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ABSTRACT

The results of building a new school in Edmonton (Alberta) in accordance with energy efficient principles are described in this report, the third and last in a series describing three projects utilizing different approaches to energy conservation. The Sweet Grass Elementary School project consisted in designing, building, and monitoring an energy efficient school. The design had to be consistent with available materials and construction methods reasonably priced. A summary of earlier reports outlines how computer simulations aided in establishing the building's design parameters. The methods of monitoring and problems encountered in making an accurate survey of the energy used are discussed, followed by a lengthy description of the mechanical systems and their operation. Problems encountered in both the mechanical systems and their operation are outlined. A short discussion is given on the reactions of the school occupants. Tables and graphs show the actual meter readings outlining energy consumption, weather, and usage factors, and show the relationship between these factors and the actual energy consumed. The school used less than half the energy used by other schools of similar size in the same locality. Calculations bear out a relatively short payback period, based on present forecasts of energy costs and increases, of under 11 years. (MLF)

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EA 015 308

SWEET GRASS ELEMENTARY SCHOOL

A STUDY IN ENERGY CONSERVATION

A research project outlining the effectiveness of
energy conservation methods employed in the
construction and operation of Sweet Grass Elementary School

Prepared for

Alberta Education

Edmonton School District #7
Design Construction Branch
Edmonton, Alberta

December 1981

82-7

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This report is prepared for Alberta Education, Planning and Research Branch, and is submitted by the Edmonton Public Schools under contract to Alberta Education. It is the third and final report on Energy Conservation Projects in Grande Prairie, Calgary, and Edmonton schools. The two previous reports are:

Energy Conservation: Energy Management
Faculty of Environmental Design
University of Calgary
Calgary, Alberta
October 1979

Energy Conservation: Modifications to Existing Schools
Calgary Board of Education
Architectural Services
Calgary, Alberta
December 1979.

Further information about these reports may be obtained from:
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ABSTRACT

The Sweet Grass School energy project consists of designing, building, and monitoring an energy efficient school.

The design had to be consistent with available materials and methods of construction, within reasonable costs. A prime concern was that the building be compatible with the school needs.

In an effort to design the building to the maximum energy efficiency, computer simulations were done for the various aspects of the design. Earlier reports outline these design parameters and the factors taken into account which determined the final design of the building.

This study will briefly condense the past studies and will conclude the results of the two year monitoring of the energy actually used.

The previous studies had established a target figure of 250 KWH/m^2/yr. This report indicates that the energy consumption was 19% greater in 1980 and 13% greater in 1981 than targetted. The reasons for not meeting the energy target are not obvious and many factors listed in the report could have a bearing on the energy consumed.

In summary, the project can be considered a success as the building is operational and provides a suitable environment, which the occupants find adequate. The energy expended to maintain the building is well below that of a building constructed to the previous standards and using conventional systems.

EXECUTIVE SUMMARY

This report will make reference to previous reports written on the Sweet Grass energy study. The earlier studies, although done before the construction of the school, influenced the construction and materials used in the final building. A basic outline of each of the reports will be given.

The methods of monitoring and problems encountered in an accurate survey of the energy used will be discussed.

A lengthy description of the mechanical systems and their operation will be given. These mechanical systems have a great bearing on the energy used since they will dictate the energy required to produce a comfortable environment.

Problems encountered in both the mechanical systems and the operation of these systems will be outlined. The amount of energy expended on these problems and the exact length of time these problems were affecting the system are not known. These factors above all else will affect the results of the energy monitoring.

A short discussion will be given on the reactions of the occupants of the school. Even though this school is operating under reduced levels of lighting and reduced fresh air quantities, the general observations of the principals were that the environment seemed quite agreeable and no complaints had been noted.

Tables and graphs show the actual meter readings outlining energy consumption, weather factors, usage factors, and show the relationship between the factors and the actual energy consumed.

Following the construction of Sweet Grass Elementary School, Dan Knott School was built, which used the building practices and similar building materials as in Sweet Grass School. There were some improvements and variations incorporated into Dan Knott School. Dan Knott may be monitored to establish its energy consumption, and the difference from Sweet Grass School evaluated.

A short discussion showing calculations bears out a relatively short payback period of under 10½ years. This payback period is based on present forecasts of energy costs and increases.

The findings show that the energy consumed over the two year monitoring period falls short of meeting the predicted target by approximately 13% in the final year. An exact reason for not attaining the target figure cannot be given, as detailed monitoring of individual systems was not done.

It can be concluded that a great deal of energy is being conserved in this school without negative effect on the users, and at a reasonable cost. This result would qualify the project as a success.

A. PURPOSE OF STUDY

The purpose of this summary is to condense the previous reports on Sweet Grass School, during the pre-construction evaluations. These studies include the computer simulations performed to establish the final design and energy efficiency of the building. This summary will also detail the monitoring of the energy use over a two year period. The methods and criteria used to determine the actual energy used and the results and recommendations obtained will also be outlined in the study.

B. PREVIOUS STUDIES

The initial report entitled "Sweet Grass Elementary School, A Study in Energy Conservation" dated June 1978, was submitted by Minsos Vaitkunas Jamieson Architects Ltd., to the Edmonton Public School Board. This study briefly outlined the proposed design of the school, in five specific areas:

The building program, showing the physical areas in square meters, the student population, and the hours of use for both the community and student population;

The design consideration in the areas of the building envelope, the mechanical systems, the electrical and lighting systems, the environmental standards, and the operation and maintenance of the electrical and mechanical systems;

The architectural design as it relates to the shape and location of the building; also the physical make-up of the building shell;

The mechanical design, relating to various alternatives available for the heating and ventilation system;

The electrical design, pertaining to lighting and other sources of electrical consumption.

These design proposals were prepared with the aid of computer program analysis. This computer program had also established that a building could be built to meet the energy consumption target of 250KWH/m2/year.

An introductory report entitled "A Study in Energy Conservation" was submitted to the Planning and Research Branch of Alberta Education, by Minsos Vaitkunas Jamieson Architects Ltd. in January 1978. This report contained a detailed discussion on the design parameters and proposals put forward in the initial report. Eight computer programs were utilized to establish:

The type and composition of the roof to be used;

The most efficient and energy effective wall design and composition;

The optimum wall heights to meet the users' needs and be energy efficient;

A comparison of energy used in existing schools in the Public School Board system;

Electrical and lighting levels to be used in the new design;

The glazing, type, size, and orientation;

Mechanical system for heating and ventilation;

The level of fresh air required for the ventilation system.

The conclusions drawn from the computer studies established the major parameters on which the actual buildings were constructed.

A supplementary report titled "Sweet Grass Elementary School Final Energy Study August 29, 1979" was developed by Yewchuk Engineering Ltd. This report dealt with predicting total annual energy consumption, capital costs, and payback period predictions based on completed contract documents. This study was done by computer simulation of the Sweet Grass School design using both its present design and construction features versus the construction standards and components found in an existing school, Brander Gardens. This report estimates a twelve year payback period. (Copies of this ten page report are available.)

The previous reports that are available are:

A Study in Energy Conservation	January 1978 (approx. 90 pages)
Sweet Grass Elementary School A Study in Energy Conservation	June 1978 (approx. 37 pages)
Sweet Grass Elementary School Final Energy Study	August 29, 1979 (approx. 10 pages)

C. ENERGY MONITORING

In order to facilitate the study of energy consumed in this school, several problems had to be dealt with. The major problem was that external portables with attaching links were to be added to the site. These portables, constructed under separate contract, were not built to the energy standards used in the school. Natural gas and electrical power services were obtained from the main systems serving the school. Since the area of the portables (400 m^2 each for north and south) represented 26% of the area of the main school building (3112 m^2), the energy consumption would greatly affect the monitoring. Separate meters were installed after the main gas and electrical meters to monitor the amount of energy consumed by the portables themselves. Since utility bills represented the total consumption of both the school and the portables, independent records had to be kept on the reading of all the meters. These readings have been recorded by the school custodian for the period of December 1979 to December 1981, on a weekly basis.

Utility bills will only reflect the total energy consumed on the site, and since utility companies tend to estimate some of the billing periods, the use of utility bills for an energy record was not considered. In the case of electrical billing the demand portion of the bill cannot be accurately separated to reflect the demand utilized by the school alone.

A byproduct of this monitoring system will be a record of the energy usage by the portables themselves. These will be useful figures since there are many identical portables attached to numerous schools in the Public School System. The energy consumption of other schools will be more accurately ascertained using this record of energy use of portables, since separate metering is not available.

Since the major factor affecting the energy used will be the mechanical system, the following general description of the mechanical systems and their operation is provided in this report. A brief summary of the electrical system will also be provided.

D. MECHANICAL SYSTEMS DESCRIPTION AND OPERATIONS

1. HEATING SYSTEM

a) General

The purpose of this system is to provide up to 93°C water to provide the necessary heat to maintain 22°C in the building.

b) Components

Heating Plant:	Consists of two (2) copper tube heating boilers with spark ignition, two (2) boiler inline circulating pumps, related supply header, return header, piping and controls, expansion tank.
Heating System Piping Loop:	Consists of two (2) base mounted circulating pumps, excess pressure control valve, related piping and controls, reheat coil, convectors, force flows.

c) Sequence

Heating Plant:

The two hot water heating boilers each have a flow switch and low water cut-off wired in series with the burner circuit. Prior to the burner being energized, the above controllers must be satisfied. The flow switch requires water flow through the piping system; the low water cut-off requires the proper amount of water to be in the system.

The two boiler circulating pumps P-3 and P-4 are provided to maintain a constant water flow through the boilers. This constant flow is recommended by the manufacturer to prevent possible hot spots on the copper tube heat exchanger. The pumps are automatically controlled by an outdoor sensor which shuts down pumps at 21°C outside air and restarts them at 18°C.

A controller sensing the common discharge from the boilers and reset manually from the local control panel and by outside air temperature, cycles the boiler gas required to maintain desired temperature. A lead-lag switch is provided on the Mechanical Room local control panel to alternate the lead boiler.

c) Sequence continued

Heating System Piping Loop:

The loop is taken directly off the boiler header and the water supply temperature to the system is the same as that in the header.

The water is circulated through the piping system by pumps P-1 and P-2. These pumps are sized for 50% standby. The pumps are automatically controlled by an outdoor sensor which shuts the pumps down at 21°C outside air and restarts them at 18°C.

On the pump discharge between the supply and return main is provided an excess pressure control valve. This valve modulates to maintain a preset differential between the supply and return mains so that the heating pumps will not dead head.

2. HUMIDIFICATION

a) General

The purpose of this system is to provide the required steam for humidification of the building. The steam is generated in a steam boiler.

b) Components

Steam Plant: Consists of natural draft boiler; related supply header; condensate receiver; chemical treatment tank and related piping and controls to prevent scaling; piping and controls.

Humidifiers: Consists of pneumatically controlled steam grid humidifiers.

c) Sequence

Steam Plant:

Boiler has a low water cut-off wired in series with the burner circuit. Prior to the burner being energized, the above controller must be satisfied. This requires the proper amount of water to be in the boiler.

Factory mounted controls have been provided on the boiler to regulate the burner operation in accordance with system demand.

Humidifiers.

Refer to Air Systems #1 and #2 General Description of Systems and Operation for steam grid humidifer description.

Boiler Feed Package:

The boiler feed package consists of a 45-liter receiver, two pumps P-6 and P-7, combination float switch and alternator, and make-up valve.

Make-up water is piped to the float operated make-up on the receiver, which maintains water level within the receiver. Also, chemically treated water to prevent scale build-up is piped to the condensate receiver. Chemically treated water is pumped from the treatment tank by a pump located under the tank. This pump is wired so that it is activated when either pump P-6 or P-7 operates.

When the boiler requires make-up water, the condensate pump is energized and water made up to the boiler until the water level is satisfied. The alternator provided will alternate the lead condensate pump after each cycle.

Blowdown valves are provided on the boiler to prevent buildup of scale. This is done by electrically interlocking a solenoid valve on the blowdown line with the boiler feed water pump, so that when either pump operates, the solenoid valve opens, allowing blowdown to occur. The rate of blowdown is regulated by a Hancock flow control valve installed in the blowdown line.

3. AIR SYSTEM #1 (CLASSROOM)

a) General

The classrooms and administration area are ventilated by means of a single duct variable volume medium velocity system.

b) Components

The air handling system located in the mechanical mezzanine consists of fresh air intake louver; exhaust air louver; fresh air, return air and exhaust air dampers; return air fan; mixing section; flat filter; supply air fan; humidifer; medium velocity duct distribution; variable volume boxes; low velocity duct distribution; air distribution diffusers or grilles and accessories; return air grilles and related ductwork; heating coil located in return air duct.

c) Air Flow Through System

When the unit is in "day" operation, the fresh air, return air and exhaust air dampers modulate as described under d) Sequence. The return air and fresh air mix in the mixed air plenum and pass through the filter section, supply air fan, medium velocity ductwork distribution, variable volume boxes and related low velocity ductwork.

d) Sequence

The system is started by an"on-off" switch located on the local control panel in the mechanical mezzanine. The operating mode, "day" or "night", of the unit is determined by a seven-day spring carryover time clock.

Mounted on the local control panel in the mechanical mezzanine is a manual timer, adjustable from 0 to 12 hours. This timer will override the time clock and place the system on "day" cycle for the time period selected.

"Day" Cycle:

When the operating mode of the system is "day" as determined by the time clock or the manual timer and with the system switch in the "on" position, the following occurs:

Return fan F-2 starts, followed by supply fan F-1 and exhaust fan F-6. At this time the damper controls and humidifier are energized.

The mixed air dampers and control valve for heating coil in return air are controlled in sequence by a controller located in the supply air fan discharge. The control point of this controller is reset by an outdoor sensor controller located in accordance with outdoor temperature to provide the following schedule:

At -37°C outdoors	21°C supply air
At 12°C outdoors	12°C supply air

The discharge air temperature can be reset manually by an increase/decrease knob located on the mechanical mezzanine local control panel.

The heating coil is provided in the return air duct so that a minimum fresh air quantity of 20% can be maintained at all times. This allows the air temperature to be controlled as per the discharge temperature controller set point. Without the heating coil, the fresh air damper would close, and the required fresh air to offset exhaust air, pressurization and ventilation requirements could not be maintained at very low outdoor temperature.

"Night" Cycle:

When the operating mode of the system is "night" as determined by the time clock, the following occurs:

The fresh air and exhaust air dampers close and the return air damper fully opens. Supply fan F-1, return fan F-2 and exhaust fan F-6 shut down.

Freeze Protection:

The system is provided with a low limit controller which, on detecting a low air temperature, will shut down the supply fan F-1, exhaust fan F-6 and humidifier, and position the mixed air dampers to 100% return air. To restart the supply fan and interlocked equipment, it is necessary to reset the controller manually. An alarm light is provided on the local control panel in the mechanical mezzanine to indicate if the low limit controller has operated.

Humidifier:

Interlocked with the supply air fan F-1 is a pneumatically controlled steam grid humidifier located in the fan discharge. When the supply air fan is energized, a controller sensing return air humidity modulates the steam control valve on the humidifier to maintain the desired relative humidity. This controller's set point can be manually adjusted by a reset knob on the mechanical mezzanine local control panel. A high limit controller is provided in the humidifier discharge. Should the humidity rise above the setting of this controller, the humidifier pneumatic valve is de-energized.

Time Clock Control:

With the supply air and return air fan magnetic starters placed in the "auto" position, the system is controlled as described. However, the running time of the system is set by a seven-day time clock. By programming the clock, the system can be shut down on weekends or nights.

Variable Volume Control:

The supply fan and return fan are provided with air inlet vanes, scroll bypass dampers which vary the amount of air delivered by the fans to the system. When a space served by a variable volume box is satisfied, the box modulates toward the minimum setting of the box to maintain space temperature requirements. This requires the system fans to provide less air to the system. The l/s variations required are done by modulating the inlet vanes and scroll bypass dampers on the fans. The controller which modulates the inlet vanes and scroll bypass damper is a static pressure controller which maintains the static pressure

Variable Volume Control continued

of the system constant. This controller can be manually reset at the central control panel by an increase/decrease knob. Inlet vanes close on fan shutdown and open slowly on fan startup.

4. AIR SYSTEM #2 (GYMNASIUM)

a) General

The gymnasium, kitchen, gym storage, boys' and girls' change and dressing rooms area are ventilated by means of a low velocity air system.

b) Components

The air handling system located in the mechanical mezzanine consists of fresh air louver; exhaust air louver; fresh air, return air and exhaust air dampers; return air fan; mixing section; filter; supply air fan; humidifier; low velocity duct distribution; air distribution diffusers or grilles and accessories; return air ductwork; heating coil located in return air duct; zone reheat coils.

c) Air Flow Through System

When the unit is in "day" operation, the fresh air, return air and exhaust air dampers modulate as described under d) Sequence. The return air and fresh air mix in the mixed air plenum and pass on through the filter section. The filter section is of 50 mm replaceable media. The air passes on through the supply fan and on through the low velocity duct distribution system. Air is distributed into the rooms through ceiling grilles into the ceiling space. The return air grille located in the gymnasium and related ductwork return the air to the unit. During "night" cycle, dampers revert to 100% return air and fans shut off.

d) Sequence

The system is started by an "on-off" switch located on the local control panel in the mechanical mezzanine. The operating mode, "day" or "night", of the unit is determined by a seven day spring carryover time clock. Clock trippers within the time clock are set as per the timetable established and reviewed with the Owner.

Mounted on the local control panel in the mechanical mezzanine is a manual timer, adjustable from 0 to 12 hours. This timer will override the time clock and place the system on "day" cycle for the time period selected.

d) Sequence continued

"Day" Cycle:

When the operating mode of the system is "day" as determined by the time clock or the manual timer and when the system switch is in the "on" position, the following occurs:

Return fan F-4 starts, followed by supply fan F-3 and exhaust fan F-5. At this time the damper controls and humidifer are energized.

The mixed air dampers and control valve for heating coil in return air are controlled in sequence by a controller located in the supply air fan discharge.

The set point of the discharge temperature controller can be manually reset by an increase/decrease knob located on the mechanical mezzanine local control panel, and is also reset through selector relay by signal received from reheat coil controllers. The temperature is reset in this manner so that the discharge temperature can be maintained as high as possible to satisfy space cooling requirements.

The heating coil is provided in the return air duct so a minimum fresh air quantity of 20% can be maintained at all times. This allows mixed air temperature to be controlled as per discharge temperature controller set point. Without the heating coil, the fresh air damper would close, and the required fresh air to offset exhaust air, pressurization and ventilation requirements could not be maintained at very low outdoor temperatures.

Separate reheat coils are installed in the supply air duct distribution to the kitchen, shower and dressing rooms, gym storage and gymnasium. From each thermostat controlling a reheat coil, a branch line is brought back to a selector relay which selects the thermostat requiring the most cooling to satisfy space requirements. The selector relay will reset the discharge air controller in order to provide the highest discharge temperature that will satisfy space cooling requirements.

"Night" Cycle:

When the operating mode of the system is "night", as determined by the time clock, the following occurs:

The fresh air and exhaust air damper close and the return air damper fully opens. Supply fan F-3, return fan F-4 and exhaust fan F-5 shut down. The humidifier is de-energized.

d) Sequence continued

Freeze Protection:

The system is provided with a low limit controller which, on detecting a low air temperature, will shut down the supply fan F-3, exhaust fan F-5 and humidifier, and position the mixed air dampers to 100% return air. To restart the supply fan and interlocked equipment, it is necessary to reset the controller manually. An alarm light is provided on the local control panel in the mechanical mezzanine to indicate if the low limit controller has operated.

Humidifier:

Interlocked with the supply fan F-3 is a pneumatically controlled steam grid humidifier located in fan discharge. When the supply fan is energized, a controller sensing return air humidity modulates the humidifier control valve to maintain the desired relative humidity. The controller set point can be manually adjusted by an increase/decrease knob located on the mechanical mezzanine local control panel. A high limit controller is provided in the humidifier discharge. Should the humidity rise above the setting of this controller, the humidifier valve is de-energized.

5. EXHAUST SYSTEMS

Exhaust Fan F-5 located in mechanical mezzanine	- Extracts air from Shower Room 23, Gang Shower Room 22, Girls' Change 24 washroom, Boys' Change 21 washroom. Fan is electrically interlocked with AS-2 time clock. Operates only when AS-2 is in the "day" mode.
Exhaust Fan F-6 located in mechanical mezzanine	- Extracts air from Washroom 05, Washroom 62, Janitor Supply 29, Staff Washrooms 12, 13 Janitor Room 59, Girls and Boys' Washrooms 57, 58, Janitor Room 45, Girls' and Boys' Washrooms 46,47. Fan is electrically interlocked with AS-1 time clock. Operates only when AS-1 is in the "day" mode.
Exhaust Fan F-7 located in mechanical mezzanine	- Extracts air from Science Room 40. Fan is used for purging the room and is not meant for constant operation.
Kitchen 25 Range Hood	- Residential range hood, located over range in Kitchen 25. Should be used only when range is in use. On/off switch located on unit.
Staff Lounge 14	- Small residential wall mounted exhaust fan located over range in Staff Lounge 14. Should be used only when range is in use.

6. ROOM CONTROL

The room control varies through the building as to method of maintaining space heating requirements. Typical methods are as follows:

a. Entrances with force-flows: A pneumatic aspirating thermostat modulates a heating control valve and cycles the fan motor via a P.E. switch. The fan blows air across the heating coil to heat the entrance to the set point of the thermostat. An aquastat is provided sensing return water temperature. Should the water temperature fall below the set point of the aquastat, the force flo will not operate.

b. Unit Heaters - Mechanical Room, Garbage Compactor Room: Water continuously flows through the unit heater coil. A line voltage thermostat cycles the unit heater fan, which blows air across the coil to satisfy space heating requirements.

c. Rooms with non-thermostatically controlled convectors: Water continuously flows through the heating coil located in the convector. The amount of heat available from the convector can be adjusted by manually opening or closing the damper.

d. Rooms with thermostatically controlled radiation: To satisfy space heating requirements, radiation is installed in the rooms. Refer to drawings for location of radiation. A pneumatic room thermostat modulates a normally open valve on the radiation. This valve allows water through the radiation element to heat the air passing through the element to satisfy space heating requirements.

On "night" cycle as determined by ventilation time clock, the thermostats shall maintain a space temperature of 16°C. "Night" cycle is overridden automatically below 0°C.

During the "day" cycle, the thermostat shall maintain a space temperature of 21°C.

By pressing a knob on any room thermostat, that thermostat will revert from "night" mode to "day" mode and maintain "occupied" temperature of 21°C for the remainder of the cycle.

e. Gymnasium Unit Heaters: The purpose of the unit heaters is to maintain space temperature when Air System #2 is off at night. A pneumatic aspirating thermostat set at 15°C modulates a heating control valve and cycles the unit fan motor via a P.E. switch.

f. Rooms with variable volume box with reheat only: The air from the air system is distributed to a variable volume box through a medium velocity duct main. Branch duct take-offs are taken from the main and run to the boxes. The box has a damper mechanically linked to a pneumatic operator, controlled by a room thermostat. Should the room cooling requirements be satisfied, the damper will position itself to the minimum l/s setting of the box. The air being discharged into the room could be as low as 12°C. In order not to overcool the room, a reheat coil is installed on the box discharge. The room thermostat also controls a valve on the reheat coil. This valve allows water through the reheat coil to heat the air passing through the coil to satisfy space heating requirements. The air is reduced from medium velocity to low velocity in the box. The low velocity air continues on through to the diffusers, grilles, etc. to maintain desired space temperature.

g. Rooms with variable volume box with reheat and radiation: The air from the air system is distributed through a high velocity duct main. Branch duct take-offs are taken from the main and run to the boxes. The box has a damper mechanically linked to a pneumatic operator, controlled by a room thermostat. Should the room cooling requirements be satisfied, the damper will position itself to the minimum l/s setting of the box. The thermostat will modulate the reheat coil valve and radiation valve in sequence to maintain desired space temperature. On air system shutdown, the temperature in the room is controlled by the pneumatic room thermostat which modulates the normally open control valve, to allow water through the radiation element to satisfy space heating requirements.

NOTE: On loss of control air, all control valves revert to the normally open or full heat position.

7. 60°C DOMESTIC HOT WATER SYSTEM

a) General

The building is supplied with domestic hot water by two domestic hot water heaters located in the mechanical mezzanine.

b) Components

The domestic hot water system consists of two domestic hot water heaters, recirculation pump P-5 and piping system.

c) Sequence

The system temperature is maintained by tankstats mounted on each heater which sense water temperature in the heater storage tank and modulate a gas valve to maintain the set temperature.

A system recirculation pump P-5 is provided. The piping system through the building is extensive. During periods of non-use, the water in the piping system would cool down due to no flow. As a result, at the ends of the branch lines, a line is run back to the heaters. This line is classified as a recirculation line. In this line, before the heaters, pump P-5 is installed. This pump maintains flow through the distribution piping so the 60°C water can be drawn off without running excessive amounts of water at the fixtures to obtain 60°C water. This pump runs continuously.

d) Time Clock Control

The running time of the system recirculation pump P-5 is done through a seven-day time clock. By programming the clock, the system pump can be shut down on weekends and nights.

8. CONTROL AIR SYSTEM

a) General

The control system is pneumatic. An air compressor complete with storage tank provides the air required for controls for the air handling units and room thermostats; air for charging the heating system expansion tank; and air for the outlet located in Gymnasium Storage for filling balls for sports use. The air for controls and room thermostats passes through a refrigerated aftercooler to remove possible moisture in the air.

b) Sequence

The control air compressor is a duplex arrangement. The compressors alternate by a time clock to maintain air pressure at approximately 550 kPa in the storage tank and to obtain even wear; however, should one compressor fail, the other will start, to provide required air. If one compressor cannot handle the required air, both compressors will come on.

The air from the storage tank for the controls passes through a refrigerated aftercooler to remove any possible moisture in the air. The air then passes through a pressure reducing valve set at 138 kPa and filter assembly, on to the control air piping system. A pop valve is provided as a safety relief valve to prevent the system pressure from going too high, in case the pressure relief valve fails. Automatic drain valves are provided on the storage tank and aftercooler, and are piped to the floor drain.

The air for the expansion tanks is taken off before the refrigerated aftercooler. An adjustable pressure reducing valve is provided to allow adjustment of air pressure for charging expansion tanks to maintain an air cushion. Separate air lines are taken to each expansion tank with separate quick couples to allow the operator to charge expansion tank as required.

9. CONTROL PANELS

Local control panels are provided to house control instruments, and on the faces of the panels are mounted status pilot lights, readout gauges, reset switches and alarm lights. Alarm lights, upon initiation, remain on until the condition is corrected.

Mechanical Mezzanine Local Control Panel:

Readout gauge (analog) provided are:

- Outdoor air temperature
- AS-1 (Classroom) return air humidity
- AS-2 (Gymnasium) return air humidity
- Radiation supply temperature
- AS-1 (Classroom) discharge air
- AS-2 (Gymnasium) discharge air

Reset and switches provided are:

Switches:

- Boiler lead-lag switch
- AS-1 (Classroom) on/off
- AS-2 (Gymnasium) on/off
- 0 to 12 hour manual timer - AS-1 (Classroom)
- 0 to 12 hour manual timer - AS-2 (Gymnasium)

Reset:

- AS-1 (Classroom) humidity
- AS-2 (Gymnasium) humidity
- Radiation supply temperature

Status pilot lights provided are:

- Supply fan F-1
- Return fan F-2
- Supply fan F-3
- Return fan F-4
- Exhaust fan F-5
- Exhaust fan F-6

Alarms provided are:

- AS-1 (Classroom) low temperature
- AS-2 (Gymnasium) low temperature

E. ELECTRICAL SYSTEM DESCRIPTION

The lighting levels at the school were reduced in an attempt to conserve energy as well as establish an acceptable level. These levels are shown in the following table.

Light Levels	Previous Light Levels, Foot Candles	Sweet Grass Levels Foot Candles
Classroom	70	50-65
Corridors	20	15-20
Gymnasiums	50	40-50
Offices	100	70-80
Staff Study & Workrooms	70	70-80

More efficient fixture lenses, ballasts, and fluorescent tubes were employed in these reduced lighting levels to further effect energy savings.

In order to attempt a more effective use of lighting, two level and task lighting were employed.

The parking lot receptacles were put on a flip-flop system which would greatly affect the demand portion of the electrical power billing. Since only one half of the receptacles are in use at any one time, both the power demand and usage are effectively cut in half for the parking lot. A separate time clock is also used to ensure there is no after hours use of the parking lot receptacles.

The electrical lighting in Sweet Grass School is powered at 120 Volt A.C. The majority of the larger electrical motors are 208 Volt A.C., three phase power.

F. PROBLEMS ENCOUNTERED

The following problems were encountered during inspections and the exact duration of these problems is not known. Problems encountered after the first year of operation were noted on the year end report (March 1980):

- The inlet vane and bypass scroll dampers on the main air system were not operating properly. They did not vary as required with the change in supply duct static pressure, nor did they maintain the proper air volume differential between the supply and return fans. The improper air differential could have at times caused the building to experience a near negative building pressure.

- The controls on the variable volume boxes which were linked to wall fin radiation had to be adjusted for proper sequencing.
- The variable volume boxes also required air volume calibration.
- The science room exhaust fan was found to be operational for twenty four hours a day. The manual switch in the penthouse, which overrides the timing switch in the science room, had been left on.
- The boiler temperature reset control was not operating properly and had to be recalibrated. This control resets the temperature of the heating boiler with changes in outdoor air temperature.
- Air filters, at the time of inspection, were in need of replacement, due to dust loading.

- Energy management problems also noted at this time were: vestibule doors propped open, and lights being left on in unoccupied rooms.

A following inspection during March 1981, revealed problems such as:

- The supply air temperature reset control was in need of calibration. This control was not varying the main units' supply air temperature properly with a change in outdoor air temperature.
- The fan inlet vanes and scroll bypass dampers were not operating properly to maintain static pressure in the ducts.

G. BUILDING ENVELOPE SURVEY

An infra-red survey of Sweet Grass School was conducted April 9, 1980, by B & B Preventive Maintenance Ltd. This survey indicated that the outer skin of the building was very tight and in good condition. With this assurance that the integrity of the building envelope had been maintained, any excess use of energy would be due to the mechanical equipment, its operation, or the actions of the building occupants.

H. USER REACTION

The environment designed into this building would seem to be adequate for a school setting. The principal mentioned that after the first year of operation, when the system corrections and air balance were totally completed, the staff found the climatic conditions in the school quite comfortable.

Some of the energy features, such as the two levels of lighting available in classrooms, are not normally utilized. The lighting in this school is at a reduced level and the teachers have not made any negative comments about it.

The energy efficient features utilized in this school (reduced lighting levels and reduced fresh air levels) do not seem to have a negative affect on the staff. There is a good possibility that the people working in this environment are not aware of these measures and are not therefore looking for problems which might be caused by these measures.

I. SCOPE OF STUDY

The scope of this summary will basically be the study of energy used in the school building. A breakdown on which items in the mechanical systems and building shell contributed to the energy use, and to what extent, is not available.

The attached charts and graphs will outline the basic factors of weather, hours of operation that will affect the consumption of energy over a given period, and the base factors used in computation.

Table 1. Degree Days

	10 Year Average	1980	1981
January	1031.6	1010.6	681.4
February	761.0	749.3	653.9
March	858.5	714.8	510.7
April	545.5	252.5	372.7
May	233.1	155.8	158.7
June	121.8	75.8	104.9
July	40.8	44.1	38.9
August	24.2	125.6	21.2
September	77.9	230.9	154.3
October	357.2	322.6	399.4
November	601.4	517.1	501.9
December	862.8	995.9	---
Total	5533.8	5195.0	

Note: The 10 year average is the degree day figures utilized by the trace program used in the previous studies. This 10 year average is actually 1967 which was considered to be an average year.

Table 2. Sweet Grass School, 1980 Gas Readings

	Main Meter Reading Cu. Ft. x 10^3	Consumption Main Cu. Ft.	Pod Meter Reading Cu. Ft.	Consumption Pods Cu. Ft.	Diff Consumption Main - Pods Cu.Ft.	Kw
January 4th	1568		65300			
		622000		176600	445400	121367
February 1st	2190		241900			
		643000		157700	485300	132244
March 7th	2833		399600			
		374000		88300	285700	77853
April 3rd	3207		487900			
		140000		31500	108500	29566
May 2nd	3347		519400			
		95000		18200	76800	20928
June 6th	3442		537600			
		29000		7700	21300	5804
July 4th	3471		545300			
		12000		7600	4400	1199
August 1st	3483		552900			
		41000		15200	25800	7031
September 5th	3524		568100			
		130000		28100	101900	27768
October 3rd	3654		596200			
		235000		57800	177200	48287
November 7th	3889		654000			
		419000		148100	270900	73820
December 12th	4308		802100			
		637000		153100	483900	131862
January 9th, 1981	4945		955200			

Table 3. Sweet Grass School, 1981 Readings

	Main Meter Reading Cu. Ft. x 10^3	Consumption Main Cu. Ft.	Pod Meter Reading Cu. Ft.	Consumption Pods Cu. Ft.	Diff Consumption Main - Pods Cu.Ft.	Kw
December 12/80	4308		802100			
		637000		153100	483900	131862
January 9/81	4985		955200			
		301000		184300	116700	31800
February 4/81	5246		1139500			
		578000		63800	514000	140065
March 13/81	5824		1203300			
		225000		62300	162700	44336
April 6/81	6049		1265600			
		146000		44900	101100	27550
May 1/81	6195		1310500			
		103000		24800	78200	21310
June 5/81	6298		1335300			
		37000		19400	23600	6431
July 6/81	6335		1354700			
		19000		19000	--	--
August /81	No Reading		No Reading			
					0	0
September 4/81	6354		1373700			
		92000		27400	64600	17603
October 2/81	6446		1401100			
		319000		83800	235200	64092
November 13/81	6765		1484900			
		309000		84300	224700	61230
December 9/81	7074		1569200			

Table 4. Sweet Grass School, 1980 Electrical Readings

	Main Meter Read KW x 120	Consumption Main Meter KW	North Pod Reading KW	South Pod Reading KW	Total Pod Consumption KW	Difference Main-Pods KW
Jan. 4	666		3105	3495		
		24720			3682	21038
Feb. 1	872		5050	5232		
		24960			4094	20866
March 7	1080		6907	7469		
		19680			2958	16722
April 3	1244		8276	9058		
		19920			2875	17045
May 2	1410		9528	10681		
		23760			3556	20204
June 6	1608		11124	12641		
		14640			1995	12645
July 4	1730		11921	13839		
		4560			252	4308
August 1	1768		12072	13940		
		8760			1004	7756
Sept. 5	1841		12504	14512		
		18240			2902	15338
Oct. 3	1993		13947	15971		
		23400			3573	19887
Nov. 7	2188		15685	17746		
		25560			4294	21266
Dec. 12	2401		17704	20021		
		18240			2377	15863
Jan. 9/81	2553		18837	21265		

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Table 5. Sweet Grass School, 1981 Electrical Readings

	Main Meter Reading KW x 120	Consumption Main Meter KW	North Pod Reading KW	South Pod Reading KW	Total Pod Consumption KW	Difference Main-Pods KW
Dec. 12/80	2401		17704	20021		
		18240			2377	15863
Jan. 9/81	2553		18837	21265		
		15840			2441	13399
Feb.4/81	2685		20081	22462		
		29640			4496	25144
March 13/81	2932		22115	24924		
		14880			1952	12928
April 6/81	3056		23103	25870		
		17280			2539	14741
May 1	3200		24350	27162		
		21960			3017	18943
June 5	3383		25885	28644		
		16080			1935	14145
July 6	3517		26899	29565		
Aug.	No Reading	19080	No Reading		664	18434
Sept. 4	3678		27346	29764		
		16680			2683	13997
Oct. 12	3815		28509	31284		
		28680			3602	25078
Nov. 13	4054		30271	33124		
		19320			2447	16873
Dec. 9	4215		31482	34360		

CHART 1

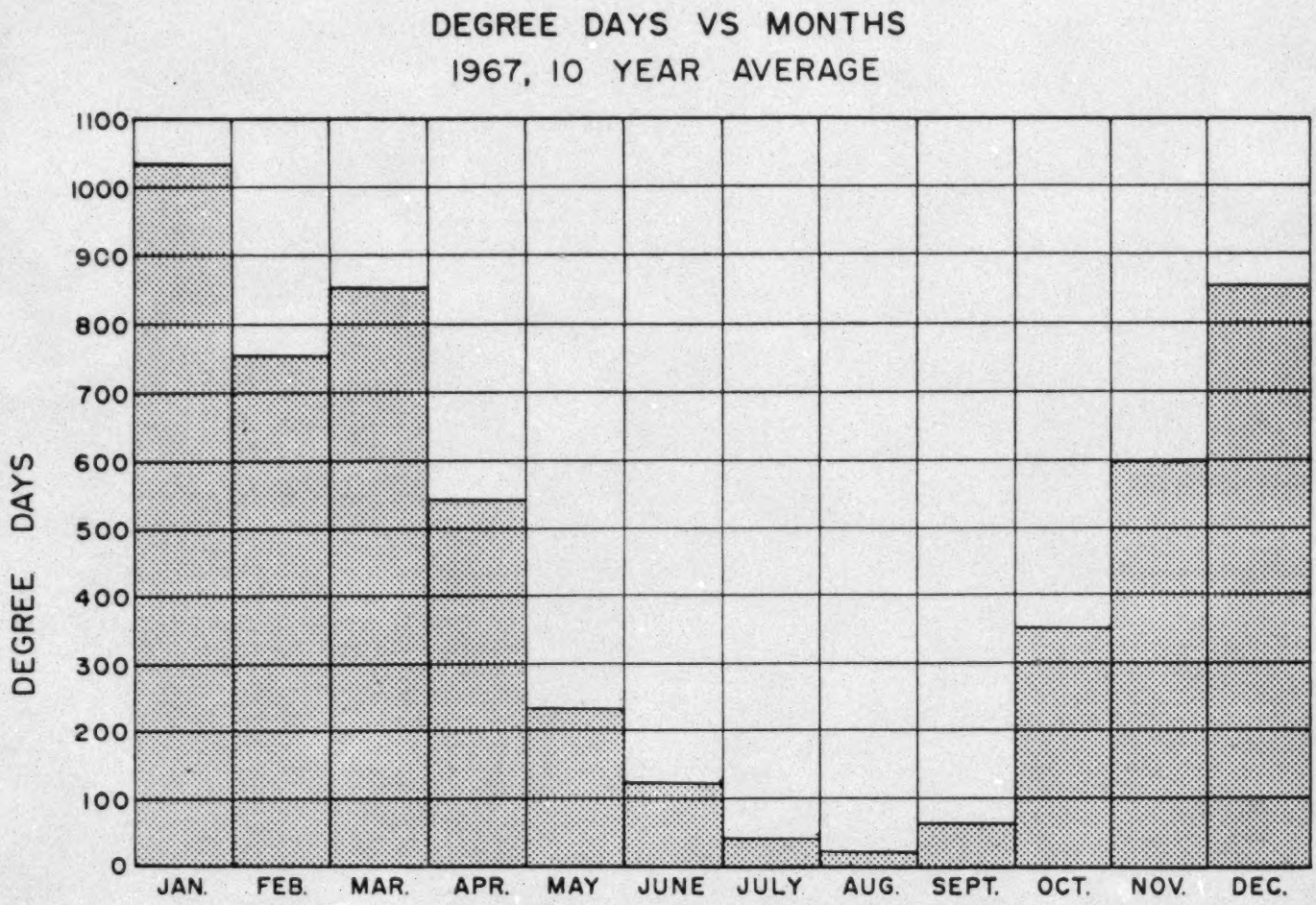

DEGREE DAYS VS MONTHS
1967, 10 YEAR AVERAGE
DEGREE DAYS
1100
1000
900
800
700
600
500
400
300
200
100
0
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

CHART 2

DEGREE DAYS VS MONTHS
1980

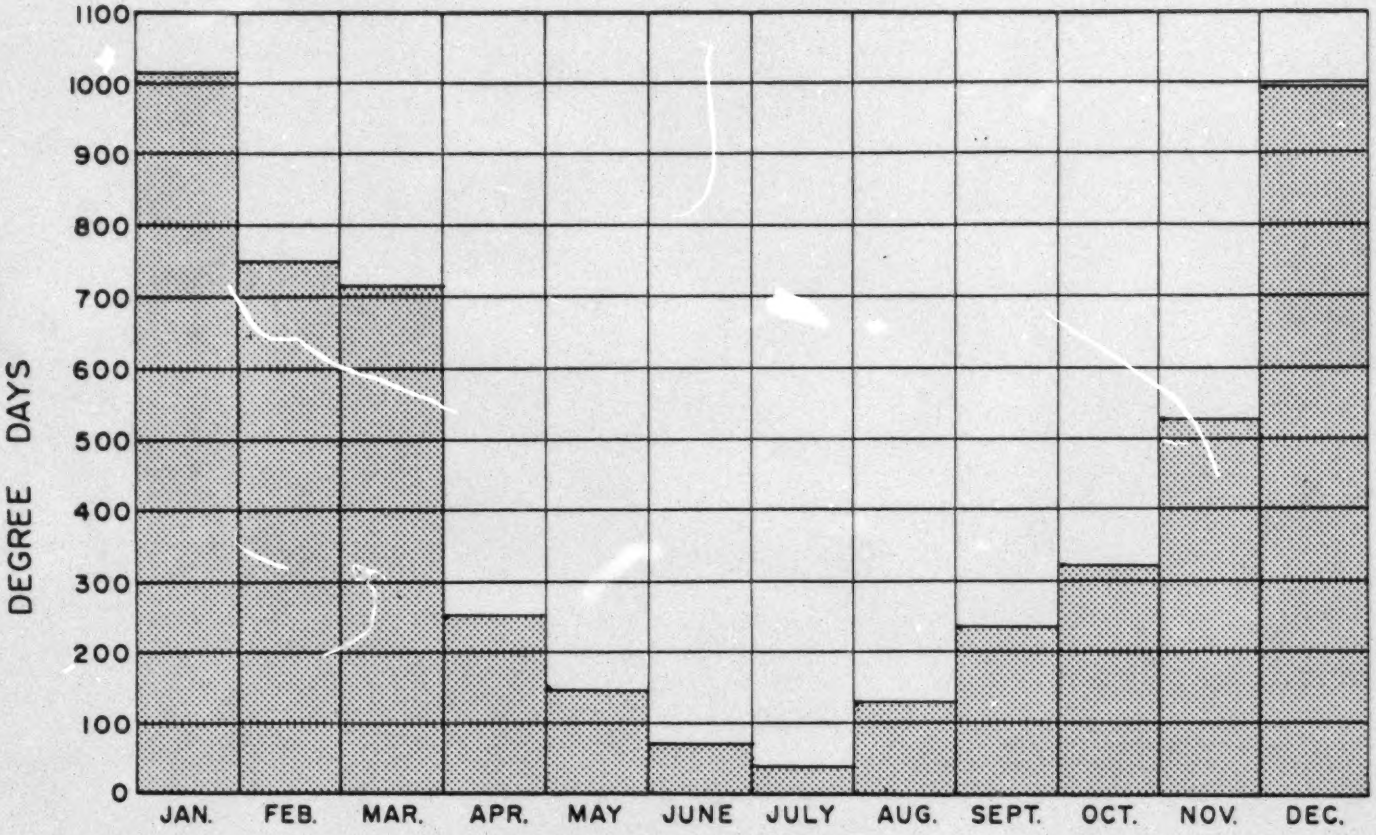


CHART 3

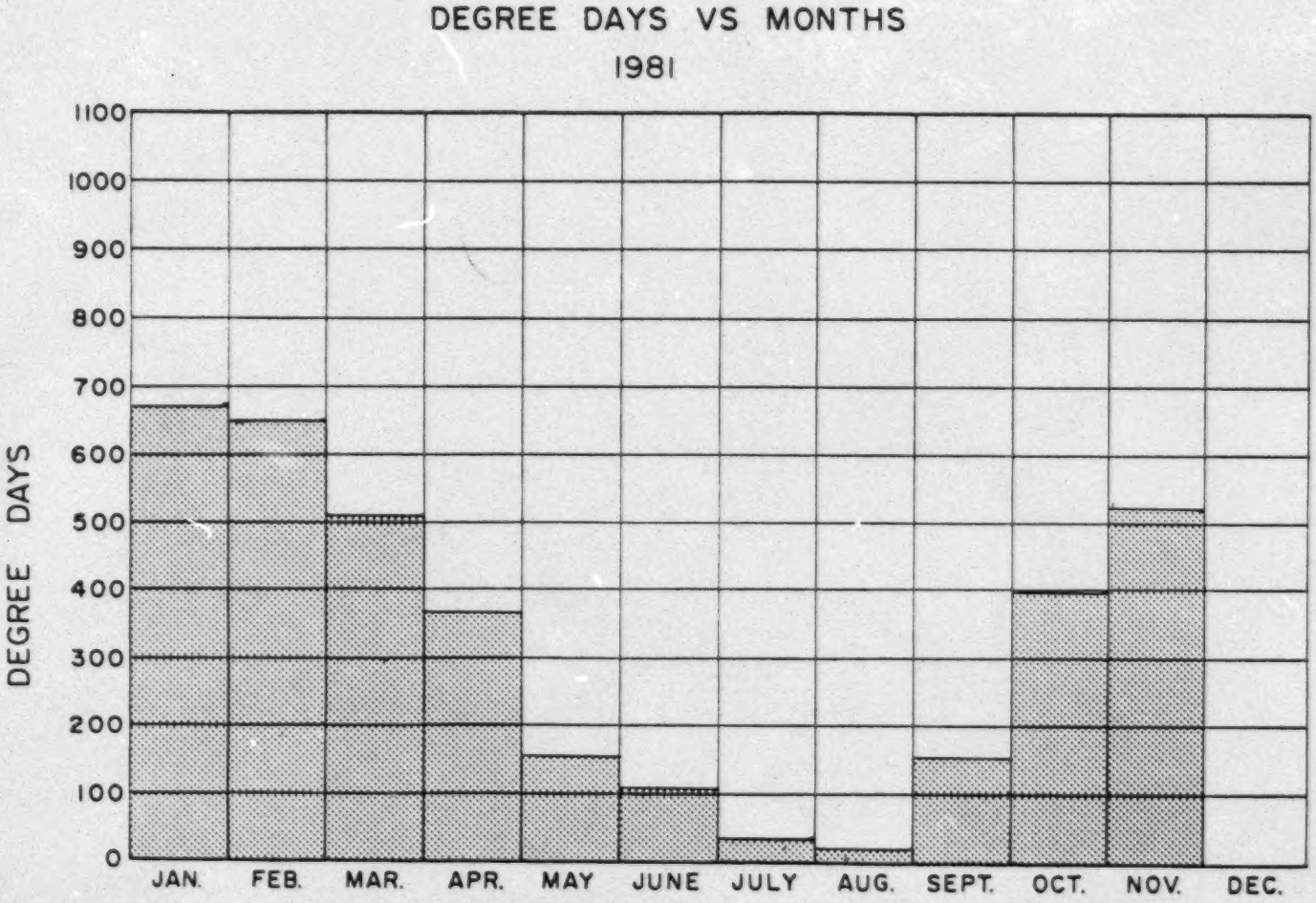

DEGREE DAYS VS MONTHS
1981
DEGREE DAYS
1100
1000
900
800
700
600
500
400
300
200
100
0
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

CHART 4

GAS CONSUMPTION IN KW
1980

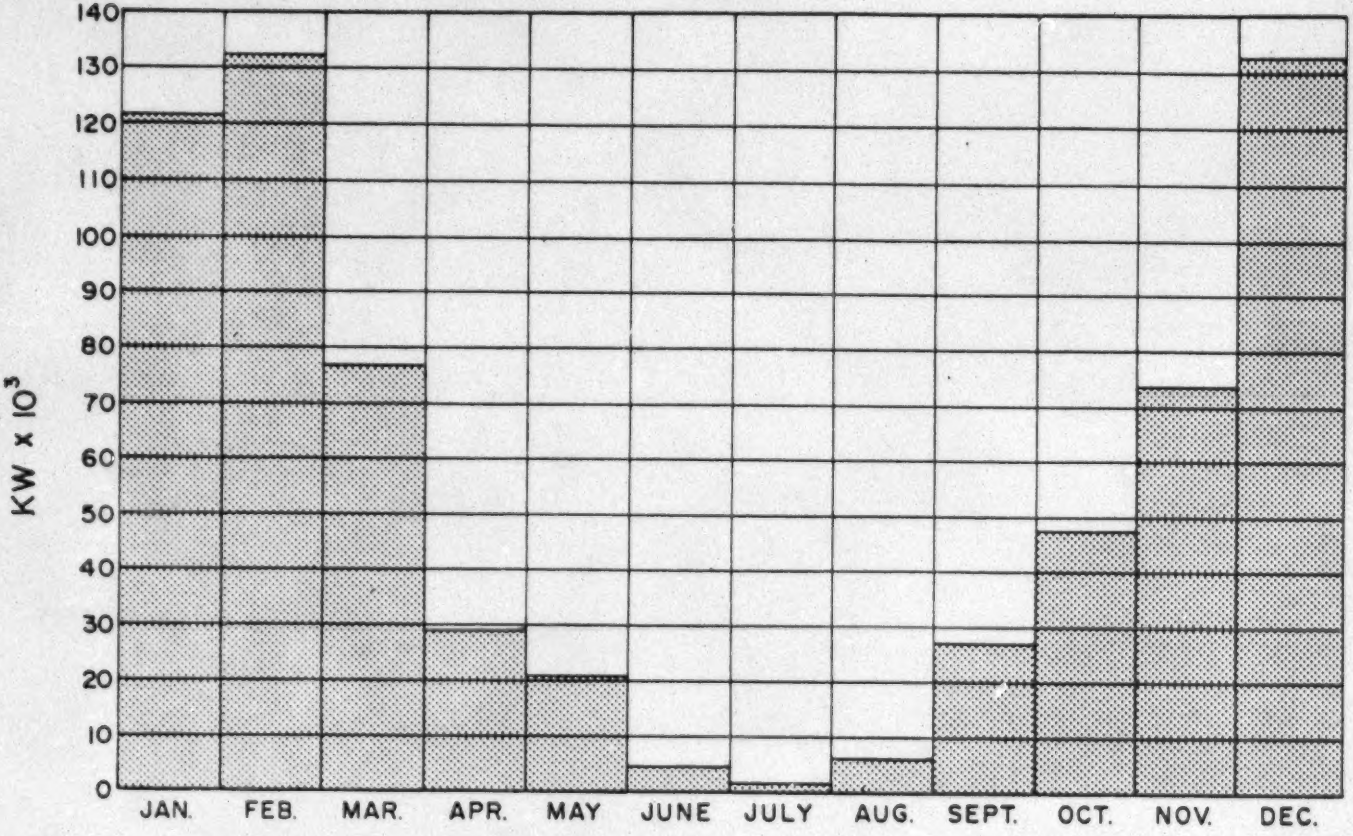


CHART 5

GAS CONSUMPTION IN KW
1981

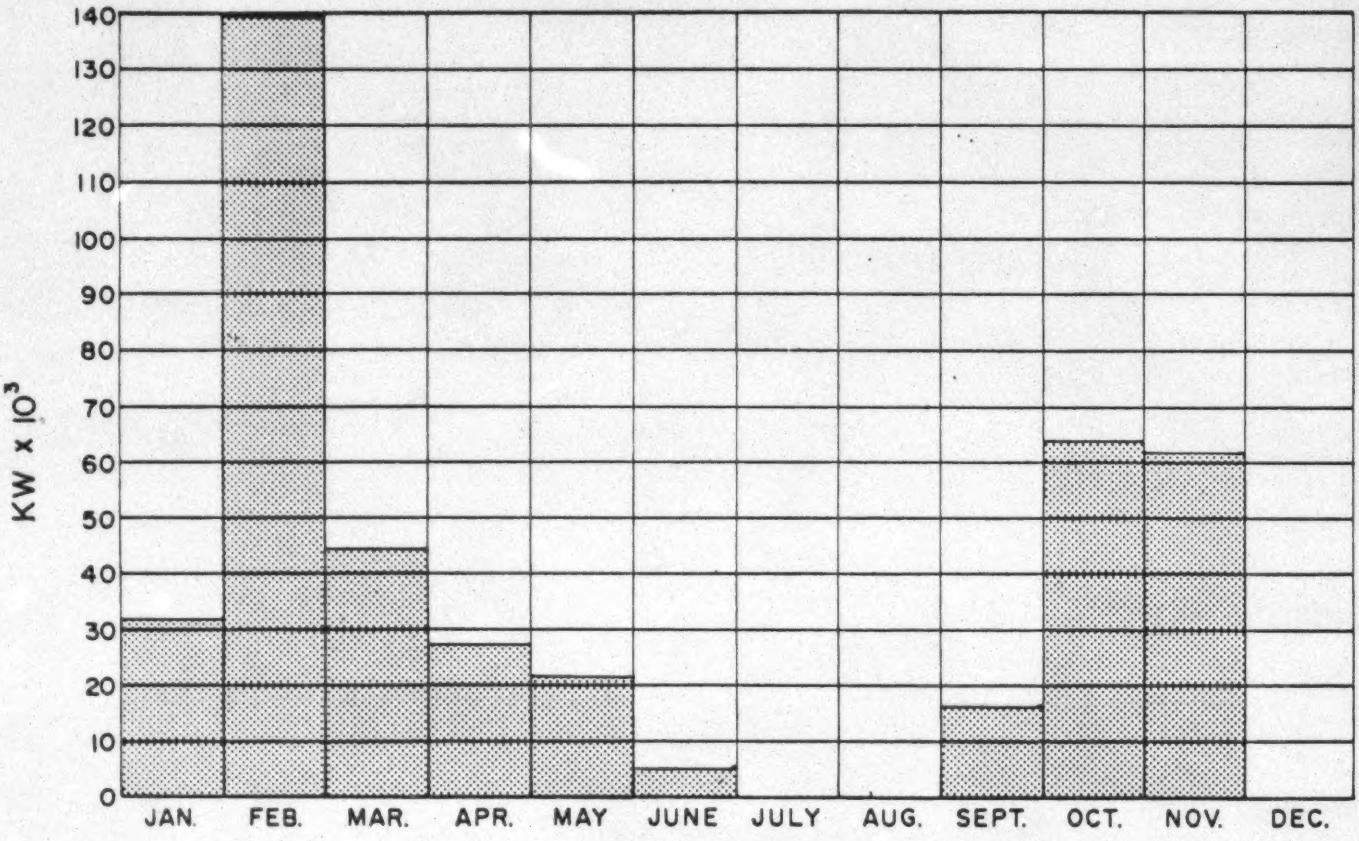


CHART 6

ELECTRICAL CONSUMPTION VS MONTHS
1980

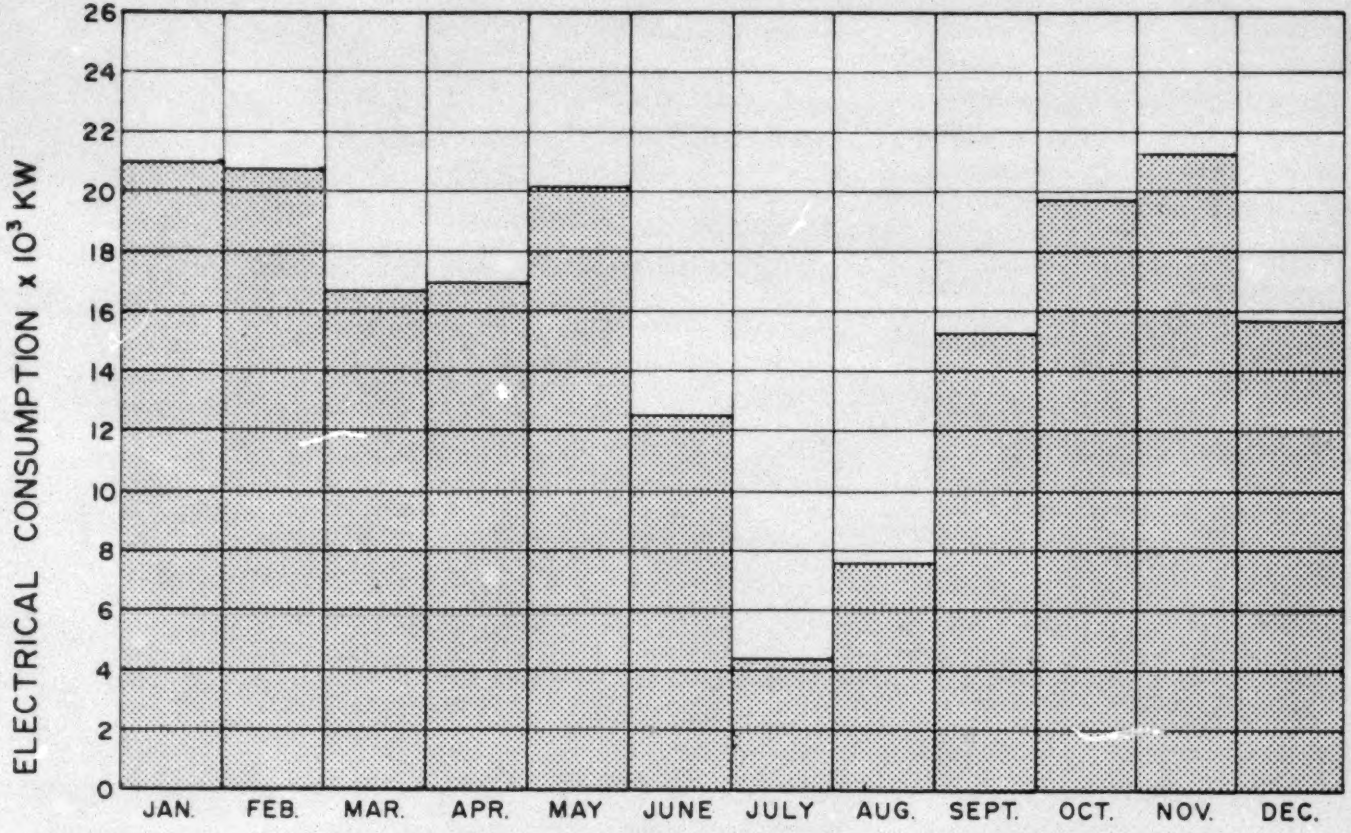


CHART 7

ELECTRICAL CONSUMPTION VS MONTHS
1981

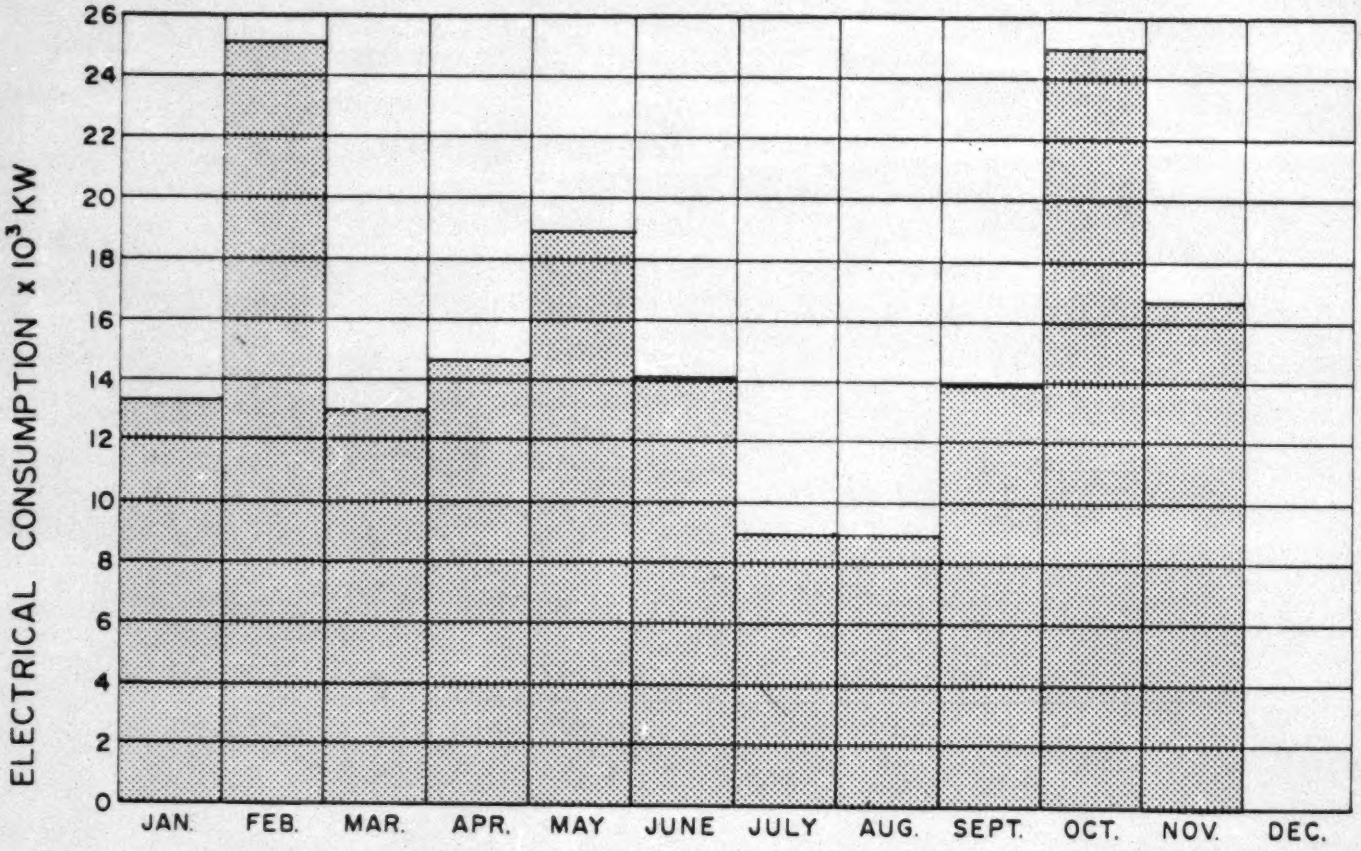


CHART 8

HOURS OF STUDENT USE VS MONTHS
1981

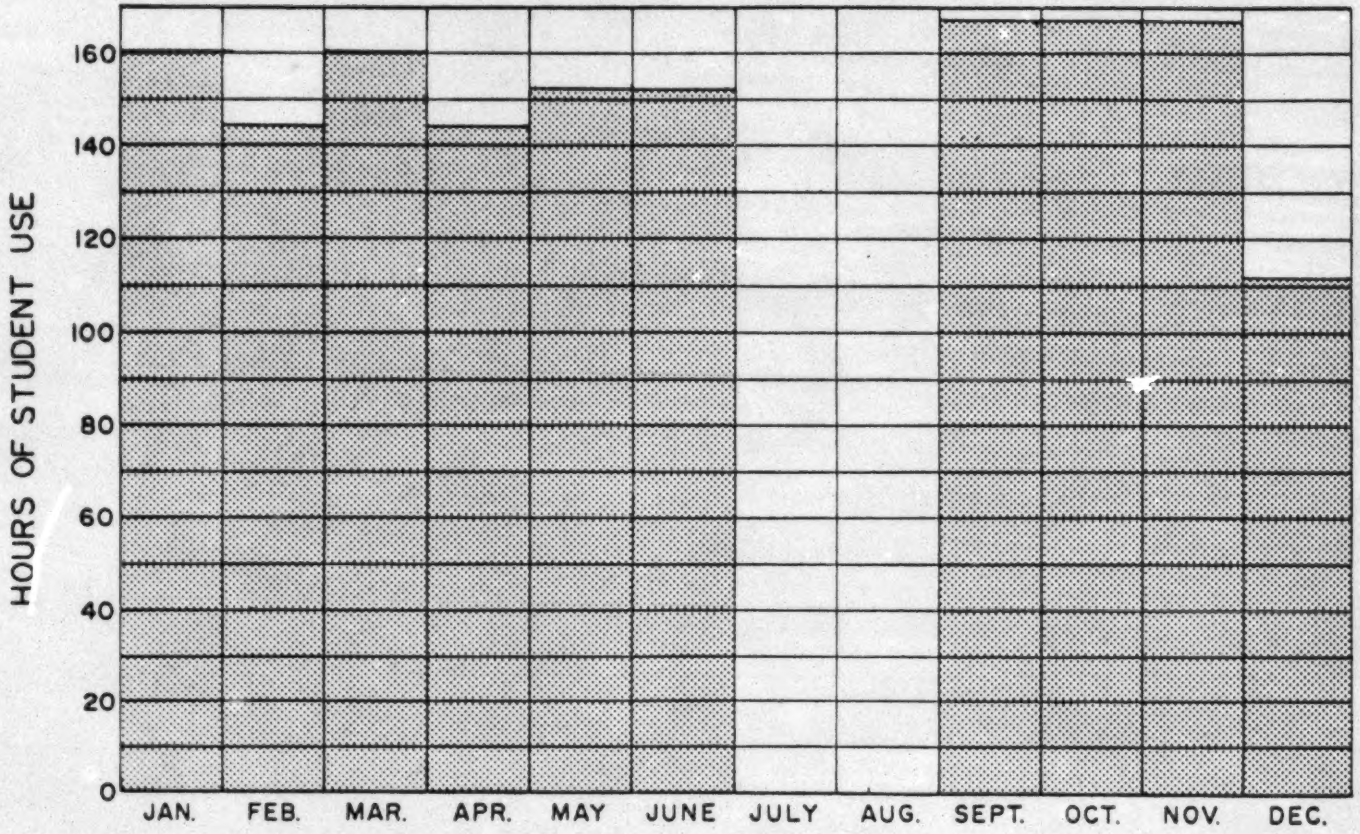
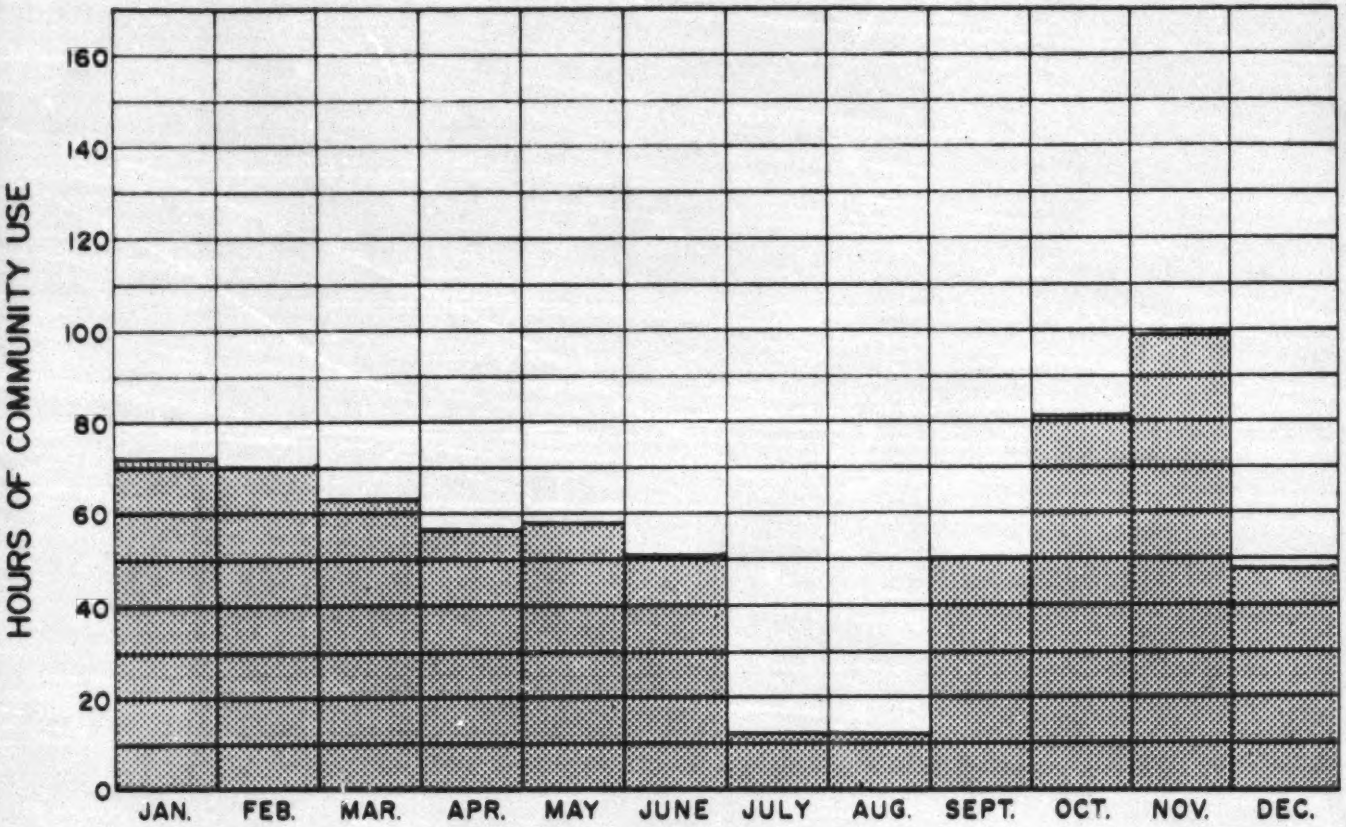


CHART 9

HOURS OF COMMUNITY USE VS MONTHS
1981



J. DAN KNOTT SCHOOL SIMILARITIES

Following the construction of Sweet Grass Elementary School, Dan Knott Junior High School was built using many of the energy features of Sweet Grass School.

Dan Knott School mechanical systems are similar to Sweet Grass in several ways:

- The main air system is a variable air volume system utilizing inlet vane and scroll bypass dampers. A major improvement to this system is the use of an "air monitor" box instead of a static pressure pick up to control the fan dampers. The system will be monitored to evaluate the effectiveness of this new control.

- All other aspects of the mechanical and related electrical systems follow the design used in Sweet Grass School very closely.

- It should be noted that the same mechanical consultant (Yewchuk Engineering Ltd.) was employed in the mechanical design of both schools.

- The lighting fixtures used in Sweet Grass were high efficiency halogen lens with energy efficient ballasts and tubes. The fixtures used in Dan Knott used only the energy efficient lens for efficient lighting.

- The parking lot receptacles are on a flip flop control in both schools. Dan Knott School construction has the additional feature of an outdoor temperature sensor which shuts down the parking lot power in warm weather.

K. COST EFFECTIVENESS AND PAYBACK

Computer simulations have been used in previous reports to predict energy consumption and a payback period. The latest report predicts a twelve year payback.

The guidelines used for these predictions were:

Additional costs of energy features: Construction cost of Sweet Grass based on contract documents compared to estimated construction cost of Sweet Grass using Brander Gardens School construction methods and materials.

A Sweet Grass School Contract Documents = $1,524,839.00

B Sweet Grass Using Brander Gardens School Methods = $1,406,779.00

Estimated Additional Costs = 118,060.00

Computer simulations were used to estimate the optimum use of energy for both modes.

A Sweet Grass School, using contract = 219 KWH/m2/yr.

B Sweet Grass School, using Brander Gardens = 329 KWH/m2/yr.

Difference = 110 KWH/m2/yr.

The utility cost estimate for methods:

A = $ 7,871.00
B = $12,084.00

$ 4,213.00 saved for the first year.

The computer study assumed a 15% increase in utility rates per year and concluded that a twelve year payback could be accomplished.

On checking previous utility rates for 1978, which was the year on which the computer study based its utility cost, the following rates were found:

Natural Gas - 1978 11.2¢/therm. = .383¢/KWH
- 1981 21.47¢/therm. = .733¢/KWH (91% increase)

Electrical 1978 0-1000 KW = 5¢/KWH
Next 2000 KW = 3.4¢/KWH
Next 3200 KW = 2.8¢/KWH

TOTAL 11.2¢ 11.2¢ ÷ 3 = 3.73¢/KWH Average

1981 0 to 850 KWH = 6.9¢/KWH
Next 5350 KWH = 4.62¢/KWH

TOTAL 11.52¢/KWH 11.52¢ ÷ 2 = 5.76¢/KWH Average

Electrical 1978 - 3.73¢/KWH
1981 - 5.76¢/KWH (54% Increase)

The average rise in utility rates would be 91% gas, and 54% electrical = 145% ÷ 2 = 72% average.

72% over four years is approximately 14.5% per year.

Previous reports have estimated a payback period of twelve years, based on a utility cost increase of 15% per year. The calculations shown for the past four years would seem to confirm this twelve year payback period. The general opinion of people involved in industry is that utility rates will escalate at a greater rate in the coming years. Utility rate increases have been estimated to be as high as 30% to 50% per year in the near future. If these increases do take place, the payback period may be revised to five years or less.

It should be noted that the payback calculations are based on the additional costs for materials and labor for energy efficient features applied to Sweet Grass Elementary School. These additional costs on Sweet Grass School were approximately 8% of the total cost of construction. Many factors influence the cost of building a school and a fluctuation of 8% to 10% is not unusual. During 1978, two schools of approximately the same area were tendered: Sweet Grass, with its energy efficient features, and Belmont Elementary School, of standard design. The contract documents on Sweet Grass showed a cost of $1,524,839.00 for the area of 3112 meters square ($489.99/m2), while Belmont Elementary School showed a cost of $1,532,800.00 for an area of 3116 meters square ($491.91/m2). These figures how that there may not be an additional cost for Sweet Grass Elementary School.

L. FINDINGS

On the initial computer study, a target figure for Sweet Grass School of 250 KWH/m2/year was established. This is the proposed standard put forward by the Canadian Government.

In order to determine the performance of Sweet Grass School using this standard, allowances had to be made for the climate of the monitored years.

In order to re-establish a target figure based on weather, a factor for weather dependent energy use also had to be established. Since the heating systems basically depend on natural gas as an energy source, this should be separated from the electrical energy, which is not basically affected by the weather.

In 1980 the energy used was:

217.76 KWH/m2/yr. natural gas	(78% of total)
62.0 KWH/m2/yr. electrical	(22% of total)
279.76 KWH/m2/yr. Total	

In 1981 the energy used was:

175.02 KWH/m2/yr. natural gas	(74% of total)
60.9 KWH/m2/yr. electrical	(26% of total)
235.92 KWH/m2/yr Total	

The corrected target figure would require a correction for degree days on the natural gas portion of the total energy, but not the electrical portion of the total energy.

1980 Degree day correction factor:
The 1980 year was recorded from January 4, 1980 to January 9, 1981.
1980 contained 5195 degree days.
10 year average contained 5533.8 degree days.

5533.8 D.D. - 5195 D.D. = 338.8 D.D
338.8 D.D. ÷ 5533.8 D.D. = 6.13%

6.13% - 100% = 93.87% Correction factor

1981 Degree day correction factor:
The 1981 year was recorded from December 12, 1980 to December 9, 1981.
1981 contained 4593.4 degree days.
10 year average contained 5533.8 degree days.

5533.8 D.D. - 4593.4 D.D. = 940.4 D.D.
940.4 D.D. ÷ 5533.8 D.D. = 17%

17% - 100% = 83% Correction factor

Corrected target figure for 1980:
250 KWH/m2/year target x 78% gas = 195 KWH/m2/year
250 KWH/m2/year target x 22% electrical = 55 KWH/m2/year

195 KWH/m2/year x 93.87% D.D. factor = 183.04 KWH/m2/yr. (Gas)
+ 55.0 KWH/m2/yr. (Elect.)
TOTAL 238.04 KWH/m2/yr. New Target

Corrected target figure for 1981:
250 KWH/m2/year target x 74% gas = 185 KWH/m2/year
250 KWH/m2/year target x 26% electrical = 65 KWH m2/year

185 KWH/m2/year x 83% D.D. factor = 153.55 KWH/m2/yr. (Gas)
+ 65.0 KWH/m2/yr. (Elect.)
TOTAL 218.55 KWH/m2/yr. New Target

The total consumption of energy for a year compared to the corrected target figure would show the following results:

(1980) Consumption 279.76 KWH/m2/yr: Target Figure 238.04 KWH/m2/yr.

The consumption exceeded the target figure by 17.5%.

(1981) Consumption 235.92 KWH/m2/yr: Target Figure 218.55 KWH/m2/yr.

The consumption exceeded the target figure by 8%.

It has been shown that the previously accepted standard of 611 KWH/m2/year energy used, can be effectively reduced, and savings of approximately 300 KWH/m2/year, can be attained. Even though the proposed target figure was not met, the actual consumption has been shown to be very close to the target figure.

M. CONCLUSION

The exact reason for not reaching our target figure cannot be given since there are many factors involved which could affect the energy use.

The base data - Weather, wind velocity and periods of sunshine are not taken into account.

- The effect of the portables due to shading.

- The accuracy of the meter readings may be suspected.

- The proper operations of the mechanical systems. System run times are also sometimes extended beyond their required time.

- The upkeep of the mechanical systems as shown in the previous sections detailing problems encountered.

- Use of lighting.

- Hours of community use of the school.

It should be noted that the actual hours of school use are lower than but within 10% of the computer estimated hours of use. The majority of the actual hours of community use are also concentrated in the colder months of the year.

At this time a complete preventive maintenance program is not being implemented. The areas that are being covered in the present preventive maintenance program are:

- Boiler, electrical controls checked twice a year.

- General maintenance system controls checked approximately every 15 months.

- Filters checked and changed once a year with the custodian looking after filters for the rest of the year.

- Roof inspection once a year, to check the general condition of the roofing.

If funds were available for a much more comprehensive preventive maintenance program, many of the mechanical problems affecting energy consumption could be eliminated.

In order to establish a clear understanding of where the energy is being used, much more involved studies and monitoring of the project should be undertaken.

This study shows that the energy consumed by Sweet Grass School is less than half that of the energy used in previously built schools, which consumed approximately 600 KWH/m2/year. Sweet Grass School can be considered highly successful in its efficient use of energy, even though the predicted target figure has not been fully attained. This project has demonstrated that energy saving construction methods and systems can be implemented in a cost effective manner while maintaining an acceptable and comfortable environment.